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Factors related to cooking quality in potatoes

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FACTORS RELATED TO COOKING QUALITY IN POTATOES

by

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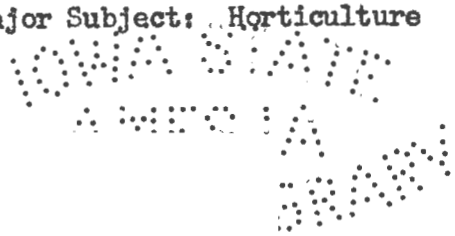

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INTRODUCTION

The quality of cooked potatoes is composed of a number of subjectively evaluated components. Mealiness, flesh color, taste and odor are the main factors used in judging potato quality. Some studies have demonstrated that mealiness and specific gravity are often closely related and are sometimes directly correlated, however, the evidence is not conclusive.

The main purpose of this investigation was to observe the relationship of specific gravity and mealiness in Iowa grown potatoes as determined by a taste panel. Since previous research has indicated that specific gravity can not always be relied upon as a consistent indicator of mealiness, this study was made to determine the effect of varieties on the variability in the specific gravity-mealiness relationship. Seven selected potato varieties grown in Iowa were used for this purpose.

Also, since color is an important attribute of potato quality, a series of color determinations were made on 74 potato selections and 9 potato varieties. The color of both the uncooked and cooked tubers was determined after different periods of exposure to air. To determine if the potato sample was subject to blackening after cooking, the alcohol plug test as used and described by Wheeler (24) was employed.

Further it has been observed that the volume of syneresis of starch gels from different plant sources such as corn, wheat and potatoes, is

not the same. Therefore, the hypothesis was proposed that the syneresis of starch gels from different potato varieties would vary; and that this variation could be used as an additional objective determination of cooking quality that could replace or increase the effectiveness of the specific gravity method. For this study the syneresis of five potato varieties for three specific gravity classes was measured.

REVIEW OF LITERATURE

Many investigations have been conducted to relate mineral nutrition and cultural practices to potato quality. Smith and Nash (19) investigated the relationship of minor elements to the chemical composition and quality of potato tubers. They reported no color, form or texture differences in the cooked tubers resulting from a deficiency of copper, manganese, boron or iron in nutrient solutions. However, they found pronounced flavor differences in tubers from different treatments. Cooked tubers from the complete, and the manganese deficient treatments were considered mild and desirable in flavor. Those tubers from treatments lacking in iron, boron, or copper were found to be the poorest in flavor.

In their investigation of the relation of sunlight to cooking quality, Nash and Smith (16) suggested that the amount of sunlight at the time of tuber formation plays an important role in determining the quality of potatoes grown in different areas, or of potatoes grown in different years in the same area.

High specific gravity has long been known to be associated with mealy potatoes. Findlay (6) stated that early planted potatoes produced dry mealy tubers, whereas late planted potatoes of the same variety produced tubers that were soggy after cooking. Likewise, Smith and Nash (20) found that tubers from early planted potatoes were consistently higher in specific gravity and dry matter than were those less mature tubers from

late planted plots. They stated that potatoes vary in specific gravity from about 1.050 to 1.110 and that factors such as varieties, fertilizer treatments, and temperatures during the latter stages of growth affect specific gravity. Nash (15) found that potatoes grown on muck soils generally have a lower specific gravity than those grown on mineral soils. Smith (18) used brine solutions to separate the potatoes into three ranges of specific gravity. Tubers below 1.070 were labeled as frying potatoes, those 1.070 to 1.080 as boiling potatoes, and over 1.080 as baking potatoes. He reported that consumers were willing to pay a premium of seven cents per five pound package of baking potatoes separated according to specific gravity than for comparable potatoes not graded by this method.

There have been many theories proposed to explain the mechanism of mealiness. One of the earliest of these theories was that of Coudon and Bussard (5) who in 1897, recognized the possibility that variation in the pectin content might be responsible for differences in mealiness. They reached this conclusion by noting the ease with which potato tissue disintegrated when cooked. However, the amount of pectin material they secured by alcohol extraction did not correlate with mealiness. Whittenburger's (25) explanation for the closely related conditions of sloughing and mealiness was based on differences in pressures developed within the cells due to swelling of starch granules during cooking, and upon the cells ability to withstand pressure. His main conclusion was that specific gravity cannot be used as an absolute criterion for mealiness since it does not differentiate between the amount of starch and other materials, such as sugar, within the individual cells of the tuber.

Although there is not complete agreement as to the superiority of baking to enhance mealiness, most authorities agree that baking is equal too, if not superior, in this respect to other methods of cooking. Butler et al. (2) stated that steaming did not alter mealiness as compared with boiling, and that baking produced at least as high a degree of mealiness as steaming and boiling. Fisher (7) on the other hand, concluded that steaming resulted in somewhat less mealiness than boiling. Sweetman (22) indicated that varieties vary in mealiness depending upon the method of cooking. She stated, for example, that the Russet Burbank potato is more mealy when baked than when peeled and boiled. According to Sweetman (22) the most important qualities to be evaluated in the palatability of cooked potatoes are texture, cohesion, color, and flavor. Establishing a standard for any of these characteristics was found to be difficult since individuals vary so widely in their evaluation of quality.

Hanson (10) stated that sensory tests may be divided into two categories: the consumer acceptance or preference tests which use the senses as a measuring device but whose object is to determine what a representative population prefers, and the sensory difference test (as typified in this study) which is used to measure differences in samples regardless of individual preference. Boggs and Hanson (1) state that subjective evaluation of palatability differences is an indispensable part of research with any food because its function cannot be fulfilled in any other way.

They also point out that numerical grading tests are used more frequently as a method of recording differences in quality rather than ranking, paired difference, triangle difference, or dilution tests. This

may be due to the fact that there is considerable latitude in the design of numerical grading tests and quantitative differences are obtained.

Sharp et al. (17), in studying flavor of storage eggs, noted that some judges were more reliable than others. The means, standard deviations and probable errors were calculated on the basis of the scores assigned by all of the judges in one group and by the best five judges in another group. The standard deviations were smaller when the data were limited to the best five judges. The means were not affected to any consistent degree, except that the best five judges gave the material being tested a more favorable score.

Marcuse (12) described a control cart method for preselecting five or six of the most consistent judges from a large group of people. The method is based upon a standard value, $\bar{X}$ that is determined by prescoring a sample of the same material by a panel of experienced tasters. The method of choosing the experienced tasters was not given.

Darkening of a raw potato tuber may be controlled by choosing a variety that does not blacken when exposed to air, or by a chemical treatment of the peeled potato. Kalmar et al. (11) found that blackening may be controlled by dipping the peeled tuber into boiling water, cooling to room temperature and then dipping them in a sodium sulphite solution followed by spraying or dipping in citric acid. Potatoes so treated remained white for three weeks if they were bagged and placed in a 38° to 42° F. storage.

Treadway and Olson (23) have outlined a similar method of treating and packaging peeled potatoes to prevent blackening of the tuber surface.

Their technique consists of peeling the potatoes by lye, steam or abrasion followed by a 30 second dip in a solution of 0.5 per cent sodium bisulphide and 0.5 per cent citric acid. They state that a longer dipping time or a stronger solution, particularly with respect to the bisulfite, strengthens the preservative action, but overtreatment may cause an off flavor in the product. Excessive acid may cause juice to leak from the potatoes.

Smith (18) stated that darkening after cooking may be reduced or avoided by adding some acidifying substance such as lemon juice, vinegar, or cream of tartar to the water before boiling the potatoes.

Smith and Nash (20) found evidence that darkening after cooking was increased if the potato plants were subjected to low temperatures and low light intensities at the end of the growing season. These same conditions also produce the most mealy potatoes. Smith (18) stated that blackening may be influenced by varietal characteristics, growing season, temperature, sunshine, fertilizers, tuber pH, and vine and tuber maturity.

The chemical processes involved in blackening of potatoes has been investigated by Nagy (14) who stated that the blackening of raw tubers is caused by tryosinase, an oxidase enzyme, acting on a phenolic substrate tryosine. It was shown that tryosinase activity is greater in discoloring tubers than in tubers which do not readily discolor. In addition they contain more tryosine or tryosine-like compounds. Nagy found that the reaction takes place in three stages, the first two of which are enzymatic in nature and the third stage an oxidation caused by the oxygen of the air.

The same type of enzymatic reaction was found by M'Intosh (13) to be involved in the formation of red color on cut surfaces of potato tubers exposed to air. The red substance changes spontaneously into a colorless substance that is finally oxidized to form melanin, which gives rise to the black coloration. The red coloration is not necessarily correlated with the black coloration because, as stated by M'Intosh (13), in an alkaline medium the black color develops rapidly and the preliminary reddening is not very marked. He further states that the pH of a tuber appears to depend to some extent on the environment in which the tubers are grown.

Chapman (3) stated that when a starch paste is allowed to cool, the whole mass sets to form a jelly-like body. The gel so formed, when allowed to stand, may separate into two phases; a clear layer of liquid is formed on the surface, leaving a more concentrated gel behind. The phenomenon of the separation of a clear liquid from a gel is known as syneresis. Chapman (3) found that when starch concentrations of one or two per cent were used, a discontinuous gel was formed and separate clumps of gel were visible. The amount of syneresis was affected by the concentration of starch used, the exposed surface area of the gel, the variety of starch used, certain added substances, and the age of the gel. Syneresis was shown to decrease with an increase in starch concentration. Syneresis increases directly as the amount of surface area of gel exposed; the larger the area exposed the greater the amount of syneresis. Chapman (3) in his investigation of the syneresis of corn, wheat, rice, and potato starch found that the volume of syneresis from equal amounts of three per

cent solutions stored 20 days at 27° F. was 20.8 cc, 8.3 cc, 9.5 cc, and 17.7 cc respectively. The addition of various salts to the starch solution may increase or decrease syneresis depending upon the salt added. Sodium acetate was found to increase the amount, and decrease the time of syneresis, to a larger degree than any other salt used by Chapman (3). Syneresis was also shown to be a progressive phenomenon. In most starch gels some syneresis occurs after 24 hours of standing, however, very little syneresis occurs after 15 hours.

METHODS AND MATERIALS

Evaluation of Mealiness by Sensory Methods

The material used in this experiment consisted of seven selected varieties from the bulked replicates of a potato yield trial grown at Ames, Iowa, in 1952. The varieties used were Irish Cobbler, Red Warba, Chisago, Kennebec, Triumph, Sebago and a seedling selection, X26-8. The trial was planted April 4, 1952 and harvested in late September of the same year. Six applications of DDT in the form of a dust or spray were applied to the crop during the growing season. No fertilizer applications were made to the area that included the yield trial. After harvest the potatoes were placed in a common storage at approximately 40° F. until January 5, 1953, when they were transferred to a mechanically refrigerated storage that was held at 40° F.

On February 5, the selected clones were divided into three specific gravity ranges; 1.065-1.075, 1.075-1.085, and 1.085-1.095. The salt solution method described by Haddock and Blood (9) was used for this separation. Four salt solutions of the following specific gravities were prepared: 1.065, 1.075, 1.085, and 1.095. Approximately 100 pounds of each variety was then divided into the four specific gravity ranges. All of the tubers were placed in the 1.065 solution. Those that floated were discarded and those that sank were placed in the 1.075 solution. The

tubers that sank in this solution were considered to be in the 1.065-1.075 class. This procedure was carried out until the 1.095 solution was reached. The tubers that sank in this solution were discarded, and the floaters were considered to be in the 1.085-1.095 class.

At the same time the varieties were separated into specific gravity groups, an Irish Cobbler control was selected that consisted of 18 tubers of similar specific gravity (from 1.079-1.081). A sample of the control was judged with each specific gravity class at the same time the varieties were evaluated as a means of determining if the judges were consistent in their mealiness evaluations from sample to sample. All of the above material was evaluated by the taste panel in less than four weeks after specific gravity separation was accomplished.

Whittenburger (25) has shown that there is no change in specific gravity of potatoes stored for 8 weeks at 35° or 50° F. Therefore, it was assumed that there was little or no change in the specific gravity of the tubers before they were used by the taste panel. However, the sugar-starch relationship probably did change during the storage period of approximately 4 weeks at 40° F.

In the work reported here, baking was chosen as the method of cooking because mealiness is a desirable attribute of a baked potato and because baking would eliminate the factor of sloughing. Preliminary baking tests were conducted to determine the internal temperature at which potatoes could be considered baked, and to determine the correlation between several tuber characteristics and baking time. Both tests were conducted at an oven temperature of 450° F. In the first test several tubers of

the same variety, and of different varieties, were baked with thermocouples placed to record the center temperature of each tuber. Temperature measurements were made with a Brown recording pyrometer. It was found that a tuber was baked when its center temperature reached 210° F. In this test, a tuber was considered baked if no hard areas could be found in the flesh when the tuber was cut open. In the second test, the relationship of the physical characteristics of a tuber to baking time were investigated. The baking process was considered completed when the center temperature of a tuber reached 210° F. From 4 different tuber measurements (circumference, total weight, and long and short diameter) it was found that the shortest diameter of the tuber gave the best indication of the time required for cooking. The correlation coefficient between the shortest diameter of 15 tubers and cooking time was 0.91. It was necessary to have all of the tubers baked at approximately the same time so that the panel could evaluate the tubers before they became cold. Butler et al. (2) stated that all potatoes lose their mealiness on cooling. Using the shortest diameter as a guide, it was possible to estimate the time of cooking so that the baking of all 16 tubers was completed within a period of five minutes.

Sixteen tubers were baked for each evaluation; two tubers of approximately the same specific gravity from each of the seven varieties and the control. The tubers were divided into two sets of tubers designated A and B. Two sets of tubers were used to overcome the problem of hollow heart. If hollow heart was found in a tuber of set A, the corresponding tuber in set B was substituted for the defective tuber in the evaluation test. The tubers from the set most uniform in size contained thermo-

couples and were the tubers judged by the panel in the majority of the tests.

Tubers from set A were placed in the oven at intervals according to the estimated time for cooking, and were removed when their center temperatures reached 210° F. as measured by a thermocouple. Set B was placed in the oven and removed from the oven according to the time for cooking estimated on the basis of shortest diameter.

After baking, tubers from both sets were slit with a knife and placed in a warming oven held at 150° F. until all of the potatoes were baked. In all cases the tubers remained in the warming oven less than 5 minutes. When all of the potatoes were baked, the tubers of set A were cut into quarters and each quarter immediately given to a judge on heated, individual dishes. Since mealiness could be evaluated more precisely in only 4 tubers at a time, the 8 pair of tubers were divided into two groups that were baked ten minutes apart. Thus the panel could judge the first group as the second group finished baking. Although the panel was allowed all the time they desired to make a judgment, in all cases each judge reached a decision in less than ten minutes. The judging was conducted in individual booths, each of which was lighted by two 20 watt warm light and two 20 watt cool white General Electric fluorescent lamps (Fig. 1).

The main purpose of this investigation was to determine the relationship of quality, or mealiness, to specific gravity. Therefore, the test of mealiness should be measurable in as precise terms as possible. Sweetman (22) used an examination of five characteristics such as the cut

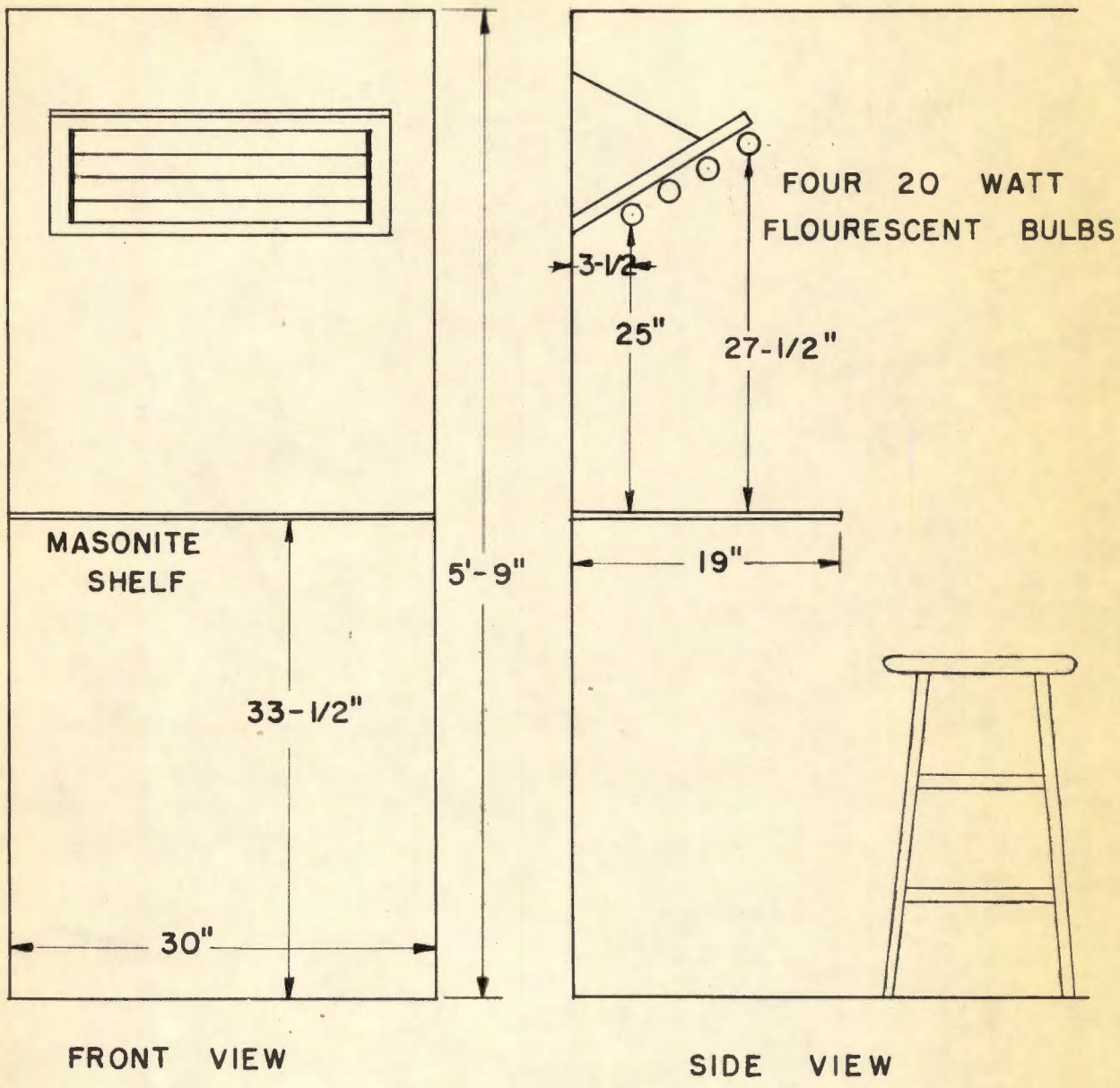

Fig. 1 Booth and lighting arrangement used by the panel in evaluating the mealiness of potatoes.

and scraped surface of the tuber, in the determination of mealiness. These characters are described in Table 1. A copy of Table 1 was given to the judges to follow in making their evaluations.

A panel of three judges was selected from a group of five people. Two of the judges had had previous judging experience and one had not judged before. The panel was selected and trained by a series of five preliminary tests. The potatoes used in two of these tests differed widely in specific gravity and mealiness to acquaint the panel members with the difference in mealiness which they were to judge. Three of the tests were identical to the judgments made in the main experiment. The method of panel selection described by Marcuse (12) was not used because experienced tasters were not available and because the material, as used in this study, did not lend itself to duplication.

The judges were asked to check descriptive terms because it is simple in technique, suitable to the problem, and because panel training is not as important with this method, as in numerical grading tests. The ranking test was not used because it does not indicate quantitative differences. All five methods of determining mealiness would have had to be weighed before a panel member could make a final judgment.

Two tests a day (one in the morning and one in the afternoon) were conducted on four consecutive days. The ninth test was conducted on the morning of the fifth day. A copy of the grading chart (Table 1) and score card (Fig. 2) were given each panel member before every evaluation. The completed score card by one judge is reproduced in Figure 2. At each

Table 1. Chart for rating mealiness in potatoes.[a]

Technic of test	Rating			
	Waxy	Slightly mealy	Moderately mealy	Very mealy
A. Cut surface (cross section about midway between stem and bud ends of tuber)	Smooth and wet	Mostly wet	Much glistening, some wet	Many glistening white particles
B. Scraped surface (at above cross section)	Wet translucent layer	Few glistening particles in layer	Layer of glistening particles that cohere	Crumbly layer of glistening particles
C. Crushed (pressure against skin of one-half of tuber)	Wet non-glistening chunks	Chunks which glisten somewhat	Small chunks which glisten and tend to crumble slightly	Crumbles into small glistening masses
D. Mashed with fork	Wet and pasty	Strongly cohering, slightly glistening	Glistening, somewhat crumbly, layers	Very crumbly, glistening layers
E. On tongue	Very smooth and pasty	Pasty, but more granular than 1	Granular but smoother than 4	Granular

[a]M. D. Sweetman (22) page 344.

Replicate # A Test # II

Judge _____

Date _____

	(Control) Code # 49				(Red Warba) Code # 17				(Triumph) Code # 80				(Chisago) Code # 44			
	(1) Wax.	(2) Sl.m.	(3) Mod.	(4) Very	(1) Wax.	(2) Sl.m.	(3) Mod.	(4) Very	(1) Wax.	(2) Sl.m.	(3) Mod.	(4) Very	(1) Wax.	(2) Sl.m.	(3) Mod.	(4) Very
Cut				X	X					X				X		
Scraped			X		X					X				X		
Crushed			X		X						X			X		
Mashed				X	X						X			X		
Tongue			X		X						X			X		
	(Total score 17)				(Total score 5)				(Total score 13)				(Total score 10)			

	(Kennebec) Code # 52				(Sebago) Code # 74				(X26-8) Code # 73				(Cobbler) Code # 60			
	(1) Wax.	(2) Sl.m.	(3) Mod.	(4) Very	(1) Wax.	(2) Sl.m.	(3) Mod.	(4) Very	(1) Wax.	(2) Sl.m.	(3) Mod.	(4) Very	(1) Wax.	(2) Sl.m.	(3) Mod.	(4) Very
Cut	X						X			X					X	
Scraped	X						X			X					X	
Crushed	X							X		X						X
Mashed	X						X				X					X
Tongue	X							X			X					X
	(Total score 5)				(Total score 17)				(Total score 12)				(Total score 18)			

Fig. 2 Score card used by three judges to evaluate the mealiness of seven potato varieties and a control. Data in parentheses were added after each test by the experimenter.

evaluation the judges were given a score card that contained only the code and test numbers, and were asked to check the term which best described the sample. The values in brackets were entered by the experimenter after the test. An arbitrarily chosen value was assigned to each descriptive term in order to subject the data to statistical analysis. Waxy was given number one, slightly mealy number two, moderately mealy number three, and very mealy number four. Scores could range from a minimum of five, which would indicate a non-mealy potato, to a maximum of 20 which would indicate a very mealy potato. Analysis of the data was by the split-split-plot method as outlined in Cochran and Cox (4) and Snedecor (21). Comparisons between varieties were made by using the standard variety, Irish Cobbler, as a control.

Discoloration of Raw and Cooked Potatoes

Seventy-four potato selections and 9 varieties grown at Clear Lake, Iowa, in 1952, were selected for blackening studies. Five tubers from each clone were used. A three-eighths inch plug was taken from the end of each tuber and placed in 95 per cent alcohol following the method described by Wheeler (24). It was demonstrated by Wheeler (24) that position on the tuber did not influence the test as long as the end pieces of the plug containing the skin and vascular area were included.

The end of the tuber that was plugged was cut off and left exposed to the air. The remaining part of the tuber was autoclaved at 15 pounds

pressure for 15 minutes. After the potatoes were cooked, a slice was cut from each tuber and exposed to the air.

The potato plug was examined for shriveling and discoloration one hour after it was placed in alcohol. The raw tuber was examined for color changes one hour after it was exposed to air and again 24 hours after air exposure. The cooked tuber was examined immediately after cooking and 24 hours later for signs of discoloration. The degree of color change was subjectively estimated by the experimenter who determined the amount of tuber surface that had turned black. A numerical score was not given to the cooked tuber color.

The raw color of the tubers after 24 hours exposure to air was divided into eight color classifications: very white, white, light gray, dark gray, cream, light brown, and dark brown. Each tuber classified gray was given a numerical color based on the amount of tuber surface that had turned black. A scale of one to four was used, each number specifying that 25 per cent of the tuber surface had turned gray. A score of two would indicate that 50 per cent of the cut surface had turned gray. The number given to the five tubers of each selection were then added to give the total score for a selection. Scores were not given to the other color classifications. Table 4 is a list of the varieties and selections classified for color with the cooked color of their tubers 24 hours after air exposure.

Syneresis

Five potato varieties grown at Clear Lake, Iowa in 1952, were selected for determining syneresis. Each variety was divided into three specific gravity groups (1.065-1.075, 1.075-1.085, and 1.085-1.095) using the salt solution method previously described. Each specific gravity group consisted of four tubers which were divided at random into two samples of two tubers each. A split-plot system of classification and analysis was used as outlined in Cochran and Cox (4) and Snedecor (21). Each sample of two tubers was macerated in a coarse food grinder and then placed in a Waring blendor for 30 to 60 seconds. The exact time of blending depended on the size of the tubers used. This time was generally not more than 60 seconds. The finely blended tissue was then filtered through six thicknesses of cheesecloth and the filtrate passed through a 6 inch Büchner funnel. The starch remaining on the filter paper was dried in an oven for 12 hours at 100° C, then finely ground and passed through a 100 mesh sieve.

A two per cent solution of starch was prepared by adding a one-half gram sample to 25 ml of a 2M solution of sodium acetate, $Na_2C_2H_3 \cdot 3H_2O$ (24.32 gr./100 ml H_2O). This was made up in 100 ml beakers which were then placed in a steam bath, covered with a watch glass containing an ice cube to prevent evaporation, and heated for 10 minutes. Chapman (3) has shown that time of heating has little effect on syneresis. Each sample was vigorously stirred at the end of the first five minutes of heating and again at the end of the heating period.

A number of identical test tubes were selected so that equal amounts of gel in each tube would have the same amount of surface area exposed. After heating, two 10 ml portions of each sample were measured into two test tubes by means of a pipette. The tubes were stoppered, stored at 40° F. for 12 hours, and the amount of syneresis determined by measuring in mm the amount of clear liquid expressed from each sample.

A uniform storage temperature was necessary because it was found in preliminary experiments that syneresis of 2 per cent starch gels formulated in 2M sodium acetate was indirectly proportional to temperature. Almost twice as much syneresis occurred in the above gels when stored at 40° F. as in the same gels stored at approximately 80° F.

RESULTS

Relationship of Mealiness Scores to Variety and Specific Gravity

The average mealiness scores determined for cooked potato tubers in three specific gravity classes in Table 2 are significantly different between all classes. The data in Table 2 indicate that under the conditions used in this study mealiness scores increase regularly from the lowest to the highest specific gravity class. The proportioning of the sums of squares due to regression in Table 3 also indicates that the relationship of specific gravity and mealiness is a direct and linear one. The samples in the higher specific gravity classes received higher mealiness scores (Table 2) except in the case of the variety Sebago.

The mealiness scores recorded in Table 2 reveal highly significant differences between varieties averaged over the three specific gravity classes. This would indicate that certain varieties were consistently scored higher than others in mealiness regardless of specific gravity of the tubers being tested. The mean mealiness score of the standard variety, Irish Cobbler, was higher than the mealiness score for all of the other varieties. The difference between Irish Cobbler and Chisago was not significant; between Irish Cobbler and Red Warba it was significant at the 5 per cent level of probability, and between Irish Cobbler and the remaining four varieties the differences were significant at the 1 per cent level of probability.

Table 2. Mealiness scores for seven potato varieties and three specific gravity classes as determined by a panel of three judges.

Specific gravity classes	Varieties							Specific gravity class means	Control mean[a]
	Irish Cobbler	Chisago	Red Warba	X26-8	Kennebec	Triumph	Sebago		
1.065-1.075	13.67[b]	14.22	11.33	11.22	10.00	11.78	11.67	11.98	12.67
1.075-1.085	17.22	14.78	12.22	13.11	14.67	11.44	8.67	13.59	13.44
1.085-1.095	18.00	17.89	15.67	15.89	15.00	13.22	10.56	15.18	11.89
Var. means	16.30	15.63	14.07	13.41	13.22	12.15	10.30		
Difference between var. means and Irish Cobbler mean	0.00	-.67	-2.23*	-2.89**	-3.08**	-4.15**	-6.00**		

Differences between specific gravity class means
(1.065 to 1.075) - (1.075 to 1.085) = 1.61*
(1.075 to 1.085) - (1.085 to 1.095) = 1.59*

LSD between means for specific gravity classes *1.25
LSD between means for varieties *2.13 **2.86

[a]The control consisted of the variety Irish Cobbler at the average specific gravity of the experiment (1.078-1.081). A sample of the control was judged with each specific gravity class at the same time the varieties were evaluated as a means of determining if judges were consistent from sample to sample.

[b]Means for three replications and three judges.

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

Table 3. Analysis of variance of the mealiness scores of seven potato varieties in three specific gravity classes by a panel of three judges.

Source of variance	Degrees of freedom	Sum of squares	Mean squares	F
Replications	2	68.96	34.48	
Specific gravity classes	2	320.65	160.32	16.88*
Linear regression	1	320.6428	320.6428	33.75**
Quadratic regression	1	.0026	.0026	
Error a	4	37.99	9.50	
Varieties	6	669.98	111.66	7.85**
Varieties x classes	12	245.35	20.45	
Error b	36	511.72	14.21	
Judges	2	27.63	13.82	
Judges x classes	4	7.32	1.83	
Judges x varieties	12	105.93	8.83	
Judges x varieties x classes	24	175.12	7.30	
Error c	84	493.33	5.87	
Total	188	2663.98		

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

The data in Table 2 substantiate the well-known relationship between specific gravity and mealiness. However, at each specific gravity class there is a varietal difference in mealiness. Therefore, some character in addition to specific gravity appears to influence the mealiness of a potato variety as judged by sensory methods employed with this panel. Similar results were reported by Greenwood et al. (8) who state that in evaluating the mealiness of new varieties of potatoes it would seem that sensory methods should be employed as well as specific gravity ratings until a more satisfactory objective method can be found.

The failure of the variety x classes interaction in Table 3 to reach significance indicates that mealiness scores of different varieties were affected in a similar way by changes in specific gravity. The non-significant interaction of judges x classes and judges x varieties indicate that the scoring of all judges on the panel was influenced similarly by varietal differences and by differences in specific gravity of the potato tubers scored.

Relatively small differences were observed among the control means for the three specific gravity classes. This indicates that the panel members were consistent in their evaluation of the control (see footnote a, Table 2).

Observations on Discoloration of Raw and Cooked Potatoes

Observation of discoloration in raw and cooked potatoes indicated a general relationship between the two. This relationship was more evident

among the varieties and selections that remained white or light gray in color when raw tuber surfaces were exposed to air for 24 hours. Twenty-four of the twenty-six varieties and selections that were white or light gray after 24 hours of air exposure when raw remained white after cooking and exposure for 24 hours (Table 4).

Ten seedling selections and the varieties, New White and Cherokee, were outstanding in their flesh color when exposed to air for 24 hours both before and after cooking. This group comprises the very white classification in Table 4. This relationship did not hold among the varieties and selections of the other seven classifications of raw color shown in Table 4. The color of the dark gray group when cooked ranged from white to light gray and from yellowish white to greenish white.

Not all of the varieties and selections that were classified white after cooking and 24-hour exposure were among those that were classified as white after similar exposure of the raw sliced tubers (Table 4). Nine of the selections that were cream colored in the raw state at 24 hours, ten of the dark gray, six of the light brown and three of the dark brown remained white after cooking and exposure to air for 24 hours.

None of the air-exposed cooked potatoes were black over the entire surface, but three (Wis. A37.51, BE2395-4 and N.43.41-1) had an undesirable dark gray or greenish white color.

These results indicate a varietal difference in the blackening of potato tubers after air exposure. They also indicate that the non-darkening characteristic is not uncommon in a potato seedling population. The

Table 4. Raw and cooked color after 24 hours exposure of 74 potato selections[a] and 9 varieties grown at Clear Lake, Iowa, 1952.

Raw color class and variety or selection	Cooked color	Raw color class and variety or selection	Cooked color
Very white (Total score of 0)		**Light gray (Total score 2-6)**	
1. Cherokee	white[b]	1. B137-5	white
2. New White	"	2. B2070-10	"
3. B2070-14	"	3. B2323-22	"
4. B2070-30	"	4. B2331-1	"
5. BE2335-42	"	5. CS10236	"
6. BE2332-37	"	6. La2402	"
7. La3676	"	7. LD92-114	"
8. Mich 172	"	8. N209.43-1	"
9. Mich B596-5	"	9. N213.43-2	"
10. OI819-1	"	10. N213.43-3	"
11. OB2423-2	yel. wh.	11. WA81.51	"
White (Total score less than 3)		**Dark gray (Total score 7-14)**	
1. BE2336-21	white	1. B2425-N5	white
2. La2396	"	2. B3232-7	"
3. N204.43-1	"	3. CS5244	"
4. BE2335-5	gre. wh.	4. CS6362	"
		5. La1859	"

[a]Prefix designates source of selections as follows: B, U.S.D.A. selections from Beltsville, Md.; BE, Indiana selection from N. K. Ellis; CS, Colorado selection from L. A. Schaal; La, Louisiana selection from T. P. Dykstra; LD, Louisiana selection from J. C. Miller; Mich, Michigan selection from E. J. Wheeler; M, Minnesota selection from F. A. Krantz; N, Nebraska selection from H. O. Werner; ND, North Dakota selection from J. H. Schultz; OB and OI, Ohio selection from J. P. Sleesman; W, Wisconsin selection from G. A. Rieman; and B2368-N1 and B2424-N5 are North Dakota selections from W. G. Hoyman.

[b]Color designations: lt. gr., light gray; gre. wh., greenish white; yel. wh., yellowish white.

Table 4 Continued:

Raw color class and variety or selection	Cooked color
Dark gray continued:	
6. La3876	white
7. M203	"
8. N104.42-1	"
9. OB738-16	"
10. WA96.51	"
11. Seneca	lt. gr.
12. CS9947	"
13. La2459	"
14. N26.44-1	"
15. N43.41-1	"
16. ND1255-1	"
17. WA70.51	"
18. La Soda	yel. wh.
19. BE2330-26	"
20. BE2355-21	"
21. N302.41-6	"
22. N700.42-23	"
23. OB478-1	"
24. OI878-1	"
25. Ontario	gre. wh.
26. BE2324-14	"
27. BE2395-4	"
Cream	
1. B2427-23	white
2. B2346-3	"
3. CS10060	"
4. CS10087	"
5. M177	"
6. M1363	"
7. WA37.51	"
8. WA49.51	"
9. WA51.51	"
10. CS10579	yel. wh.
Cream continued:	
11. M1747-5	yel. wh.
12. B2878-1	cream
13. B2878-14	"
14. CS10454	"
15. B2878-1	"
16. B2878-14	"
Light brown	
1. Red Pontiac	white
2. LD92-100	"
3. OB738-17	"
4. OB639-2	"
5. WA47.51	"
6. WA53.51	"
7. WA38.51	lt. gr.
8. WD49.50	yel. wh.
9. WD83.50	"
Dark brown	
1. Cobbler	white
2. Progress	"
3. Mich 469-5	"
4. Mich 42	yel. wh.
5. Katahdin	cream

non-darkening characteristic may become increasingly important because of the demand for varieties suitable for processing and marketing as prepeeled potatoes.

A red color was observed to form on the cut surfaces of some of the raw tubers of certain selections. This might be found anywhere on the cut surface, or sometimes only in the central portion of the cut surface and sometimes only in the periderm region; or occasionally in both regions. The time required for development of red color on the raw cut surfaces also varied. On tubers from a few selections it would form within three or four minutes, on others it required as much as one hour. In all cases it disappeared within 24 hours, with tubers turning from light gray to very dark following the early development of red color. There was no apparent association between red color formed on the raw, cut surface and the final raw or cooked color. These observations are in agreement with those of M'Intosh (13).

The attempt to predict blackening of cooked potatoes following the method of Wheeler (24) was not successful because of the lack of samples that showed any marked tendency to blacken upon cooking. The potato plugs soaked one hour in 95 per cent alcohol showed no color changes or excessive shriveling which would indicate a tendency to turn black upon cooking. In a few cases there was some brown discoloration confined to the vascular ring but this was not found to be associated with the coloration of exposed cooked tubers.

Syneresis Experiments

Highly significant differences were observed between the variety means for syneresis presented in Table 5. There is no general trend in the progression of the syneresis means from one specific gravity class to another, and as indicated by the highly significant interaction of variety x classes (Table 6), the varieties did not show similar changes in syneresis in response to changes in specific gravity.

The high significance between the variety means for syneresis would indicate that a given variety was consistently high or low regardless of the specific gravity of the tuber from which the starch was extracted. The data in Table 5 show that the mean syneresis of starch gels from the variety Progress was significantly below that of the same kind of sample from the check variety Irish Cobbler. There was no significant difference between means for syneresis of starch gels extracted from tubers in the three specific gravity classes.

Table 5. Syneresis means measured in millimeters of expressed liquid from starch gels of 5 potato varieties.

Specific gravity classes	Varieties					Class means
	X26-8	Katahdin	Irish Cobbler	Cherokee	Progress	
1.065-1.075 (cl.1)	41.00	38.25	37.38	39.38	35.00	38.20
1.075-1.085 (cl.2)	42.25	40.88	40.50	37.75	38.13	39.90
1.085-1.095 (cl.3)	40.88	44.13	41.13	41.25	37.63	41.00
Var. means	41.38	41.09	39.67	39.46	36.92	
Difference between varieties and standard variety Irish Cobbler	1.71	1.42	0	-.21	-2.75**	
LSD between two varieties					*1.87	**2.50
LSD between two varieties within specific gravity classes					*3.25	**4.35

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

Table 6. Analysis of variance of the syneresis, in millimeters, of expressed liquid from the extracted starches of 5 potato varieties.

Source of variance	Degrees of freedom	Sum of squares	Mean squares	F
Replications	3	660.53	220.18	
Specific gravity classes	2	159.20	79.60	
Error a	6	443.67	73.95	
Varieties	4	300.62	75.15	14.74**
Varieties x classes	8	147.38	18.42	3.61**
Error b	36	183.80	5.10	
Determinations	60	78.00		
Total	119	1973.20		

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

DISCUSSION

There is evidence from the literature that total solids content of potato tubers as measured by specific gravity is closely associated with mealiness of the cooked product as judged by sensory methods. However, there seems to be some other factor or factors which make one variety preferred over another. While specific gravity of potato tubers provides a convenient measure of total solids content and consequent mealiness within a variety it seemed that this characteristic could not be relied upon as an infallible measure for all varieties. The evidence secured from the use of a panel of judges indicates that some varietal characteristic causes judges to score certain varieties higher than others even when care is taken to select tuber samples having the same specific gravity.

In general the data indicate that the more mealy potatoes were also the highest in specific gravity (Table 2). However, it is evident that some varietal characteristic, or characteristics, other than the measurement of dry matter by specific gravity should be considered in determining the mealiness of cooked potatoes. A characteristic such as flesh color or the glistening of the starch particles may be the reason some varieties received a higher mealiness evaluation by the judges. It seems that mealiness, or quality, will necessarily be based upon the evaluation of a combination of factors. Specific gravity or dry matter content alone is not sufficient.

Although the difference between the average mealiness scores for specific gravity classes is not significant, the mealiness scores for the variety Sebago seem to indicate that mealiness and specific gravity are not directly related. Thus, the variety Sebago may be worthy of future study to investigate the characteristic or characteristics, in addition to specific gravity, that influence the mealiness of potatoes.

It was thought that there might be a point in the range of specific gravity at which the association with mealiness might not be close enough to be detected by sensory methods. It seemed probable that the specific gravity-mealiness relationship might remain constant up to a certain specific gravity level, and beyond this point the cooked potatoes might be judged to have uniform mealiness regardless of their specific gravity. The significance of the variance due to linear regression in Table 3 indicates that this is not true; at least it is not true over the range of specific gravities included in this study. The specific gravity-mealiness relationship seems to be a direct and linear one.

A raw tuber that was white or light gray colored when exposed to air for 24 hours, generally remained white when cooked and exposed to air for 24 hours. No similar relationship existed between the dark gray tubers and their cooked product. The relationship between white or light gray colored raw tubers and their cooked color might be useful to potato breeders in selecting varieties that will not darken after cooking. At the same time it might also be of value to the breeder to determine the extent of blackening in raw sliced potatoes as a means of selecting varieties for the prepeeling process. With the introduction of prepeeled

potatoes for use in restaurants and hotels, color changes induced in such potatoes have become important. The present methods of preventing blackening in prepeeled potatoes, described by Kalmar et al. (11) and Treadway and Olson (23), might be eliminated or made more effective by the development of potato varieties that remain white when exposed to air. The importance of varietal differences in the prepeeling process is not known. Neither are the effects of cultural and storage practices well established. Further work on the importance of such factors is needed. The high proportion of seedling selections (27 out of 74) that remained white or light gray after 24 hours of exposure to air indicates that such varieties should not be difficult to select. No attempt was made to evaluate the effect of storage upon the color of raw or cooked tubers because all of the tests were conducted within 30 days after the potatoes were harvested. More experiments are needed to establish if there is a rigid relationship between discoloration of the raw tuber and that of its cooked product.

Evaluation of the cooked and raw color was found to be the most difficult part of the problem. The method used has many disadvantages, the principle one being its lack of precision. It was chosen because of its simplicity. The main difficulty in determining the color of a raw or cooked tuber is variability over the tuber surface. The center of a tuber may be snow white while its edges are dark gray or black. Future work might develop a method of blending the surface color, perhaps by rapidly rotating the tuber, and matching the blended color with color standards.

The non-significance of differences between means for the syneresis of starch gels extracted from tubers in the three specific gravity classes (Table 5) indicates that specific gravity of the potato tuber is not closely associated with syneresis. The high significance of the varieties x classes interaction also indicates that the effects of varieties on syneresis is not related to the specific gravity of tubers from which starch is extracted. Something other than specific gravity of the potato tuber appears to be associated with the amount of syneresis of starch gels from different varieties.

Because of the close association between specific gravity of potato tubers and mealiness of the cooked product, and a lack of association between specific gravity and syneresis, it seems unlikely that this phenomenon is associated with mealiness. Unfortunately there were not enough tubers for the syneresis tests from the lots of potatoes used in the panel experiments. The data at hand do not provide sufficient evidence to say definitely that syneresis is not associated with mealiness as it is judged by sensory methods. However, it is felt that such an association is unlikely.

SUMMARY AND CONCLUSIONS

Seven potato varieties grown in Iowa were evaluated by a taste panel of three judges to determine the relationship of specific gravity of tuber samples and mealiness of the cooked product. Differences between the mealiness scores for varieties averaged over all specific gravity classes were highly significant. Thus, there was some factor other than specific gravity that influenced the evaluation of mealiness by the judges. This factor affected all of the judges the same way, since certain varieties were consistently scored high in mealiness and others were scored low. Apparently specific gravity should be used in conjunction with other tests or observations in assessing mealiness of baked potatoes.

A significant linear relationship was found between mealiness scores and specific gravity of potato tubers. The relationship between specific gravity of tuber samples and mealiness scores remained constant over the range of specific gravity used in this experiment. The judges were able to discern differences at high as well as at the low range of tuber specific gravity. The judges did not differ significantly in their ability to score mealiness by the sensory methods used. The statistical analysis of mealiness scores showed no significant differences due to judges, or to interactions of judges x varieties, and judges x specific gravity classes.

Tubers of 74 seedling selections and nine varieties were examined for color changes before and after cooking. A general association was observed between the discoloration of raw and cooked potatoes when the raw color remained white or light gray after exposure to air for 24 hours. The majority of the selections and varieties that were classified white or light gray after 24 hours exposure of the raw sliced tuber also remained white 24 hours after cooking. The color of the cooked potatoes varied from white to dark gray, from cream to dark brown, and from yellowish white to greenish white. Ten seedling selections and the varieties Cherokee and New White were outstanding in the whiteness of their flesh color both cooked and raw when they were exposed to air for 24 hours.

A cooked product with a light color is preferred by consumers. Raw potato color has become important in recent years with the introduction of ready-to-cook potatoes for use by hotels and restaurants. The data presented in this study indicate that there may be a general association between white and light gray color of raw tubers after air exposure and the color of cooked tubers after exposure. It may be possible for potato breeders to accomplish some selection on the basis of discoloration of raw sliced potatoes exposed to air. A wide range of differences in discoloration of the raw pared tuber was observed among seedling selections. If the inherent ability of a variety or selection to remain white after paring is of value in the processing of prepeeled potatoes it will not be difficult to select this characteristic from populations of seedling potatoes.

The starch syneresis of five potato varieties at three different specific gravity classes was examined to determine whether syneresis could be used as an objective measure of mealiness. The syneresis of the varieties differed significantly, but the differences were not related to specific gravity. From this it seems unlikely that syneresis is related to mealiness.

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